THE LINKAGE BETWEEN PUBLIC AND PRIVATE INVESTMENT:

A CO-INTEGRATION ANALYSIS OF A PANEL OF DEVELOPING COUNTRIES

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While economists agree that investment has a positive effect on economic growth, they have not produced a consensus on whether public or private investment has a larger impact on economic activity and whether there is a link between the two. A frequently cited study by Aschauer [1989] highlighted the importance of public investment, indicating that the decline in public infrastructure spending explains large part of the productivity slowdown in the US economy in 1980s. Following this study, there has been a growing body of literature that investigates whether public investment leads to an increase in output growth and/or the productivity of private capital [e.g., Munnell, 1990; Khan and Reinhart, 1990; Barro, 1990; Easterly and Rebelo, 1993; Tatom, 1991, 1993; Evans and Karras, 1994a,b; Ramirez, 1998; Khan and Kumar, 1997]. The hypothesis has been tested either directly, using a neoclassical production function where public capital enters as a separate input, or indirectly by looking at the productivity of private capital and labor, and the rate of return to private capital derived from the production function. Overall, the empirical evidence from the US and from developing countries suggests that private capital is more productive than public investment, and that although public investment contributes to the productivity of private capital, it does not explain the major part of the variation in output growth.

The finding that public investment contributes less to overall productivity than private investment does not necessarily undermine the role of public investment, because public investment may increase productivity indirectly by enhancing the productivity of private capital. For example, public infrastructure expenditures may be complementary to private investment. Another approach to examining the effect of public investment on economic growth and productivity is, therefore, to test the hypotheses that public investment either promotes or displaces private investment by specifying a private investment model. There have been a small number of studies using a model of private investment to address this hypothesis. The studies by Greene and Villanueva [1991] for a panel of developing countries and Ramirez [2000] for a panel of Latin American countries found that public investment stimulates private

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investment. Blejer and Khan [1984], Odedokun [1997] for a panel of developing countries, and Oshikoya [1994] for a panel of African countries presented evidence that public infrastructure (represented by the expected public investment and/or its trend level) has a positive impact while non-infrastructure investment (the unexpected component and/or deviations from its trend) has a negative impact on private sector investment. Single-country studies, however, show more mixed results as to whether public and private investment are complements or substitutes [Ramirez, 1994; Erenburg and Wohar, 1995; Nazmi and Ramirez, 1997; Ghali, 1998; Apergis, 2000]. These studies use either a flexible accelerator model or an informal model of private investment where the dynamic structure of private investment is defined as a partial adjustment mechanism, and thus do not take advantage of the broad framework provided in the literature of investment behavior and its dynamic structure.

This paper adds to the literature by examining a neoclassical investment model within an error correction framework to investigate the link between public and private investment. The model is modified to incorporate uncertainty, which affects private investment because of the irreversibility of investment. Recent theoretical studies that model private investment behavior consider investment to be irreversible because capital investments are often firm specific resulting in the sunk cost associated with the initial cost of investment [e.g., Abel, 1983; McDonald and Siegel, 1986; Pindyck, 1991; Caballero, 1991; Dixit and Pindyck, 1994; and Abel and Eberly, 1994; 1995a,b]. Public investment may play a role in reducing uncertainty by providing complementary investment (e.g., infrastructure), by showing by example that investment in a country can be profitable, and by enhancing the operation of credit markets. This paper incorporates the conditions of uncertainty into the framework by constructing an appropriate proxy, and makes a clear distinction between the short run and long run effects of public investment. Finally, the paper addresses a potential problem of spurious regression bias by performing cointegration tests. The results show that there is a complementary relationship between public and private investment in developing countries both in the long run and short run.

THEORETICAL DISCUSSION AND SPECIFICATION OF EMPIRICAL MODEL

Public and Private Investment

Many channels that relate public investment spending to private investment have been identified in the literature [e.g., Buiter, 1977; Barth and Cordes, 1980; Aschauer, 1989; Ramirez, 1994; Erenburg and Wohar, 1995]. First, public investment may increase aggregate output and thus enhance the physical and financial resources in the economy. Second, public spending on infrastructure such as roads, highways, education, sewer and water systems, and power plants often results in a reduction in costs facing the private sector. Such infrastructure investments by the state complement private investment, raising the productivity of private capital. However, there are some cases in which public investment may negatively affect private investment. For example, if the public and private sectors compete for the same resources in the economy, the costs of financing private investment increase while the availability of credit to the private sector declines, which could crowd out investment in the private sector. Furthermore, investments undertaken by highly subsidized state economic enterprises are often financed through the printing press, external debts and deficit spending. High fiscal deficits may reduce the available credits and/or raise interest rates, crowding out the private sector from profitable investment opportunities. Finally, public investment may substitute for private investment when they both produce goods and services that are in direct competition in a marketplace, and especially if public production is subsidized by the government. Public investment plays many competing and offsetting roles in its effect on the investment activities of the private sector, so the net effect of public investment on private investment is an empirical question.

Irreversible Investment and Uncertainty

Analytical studies identify several competing mechanisms through which uncertainty affects investment decisions. Dixit and Pindyck [1994] develop an option-based model of irreversible investment under conditions of uncertainty where the ability to delay an irreversible investment decision is similar to a financial call option. The possibility of postponing an investment project has a cost as well as a benefit, but the net effect is that uncertainty reduces the attractiveness of ex ante investment. In contrast, Abel and Eberly [1995a; 1995b] argue that the negative effect of uncertainty and irreversibility does not necessarily hold in the long run. Despite the short-run disincentive to invest, there is a possibility of a “hangover effect” and thus irreversibility and uncertainty may result in a larger amount of investment in the long run. Firms might want to sell some excess capital, but cannot exercise this option because of irreversibility. Overall, the effect of uncertainty on investment is ambiguous on theoretical grounds, again presenting an empirical question.

Empirical Model

The model developed here is a modification of the neoclassical model that incorporates the effects of public investment and uncertainty, and specifies the dynamic structure of private investment as an error correction mechanism. According to the neoclassical model of investment, incorporating public capital into the optimization problem of a representative firm under certainty, the optimal or steady state level of the private capital stock is expressed as a function of output, the user cost of capital, and quantity of public capital [Sundararajan and Thakur, 1980; Ram, 1993],

$$K^*_{pt} = F\,(Y_t, C_t, K_{gt}) \tag{1}$$

However, under the conditions of uncertainty and irreversibility, this needs to be modified with the inclusion of uncertainty because uncertainty may have an impact on the long run equilibrium (steady-state level) as well as the short run dynamics of private capital [e.g., Price, 1996]. Thus the equation becomes,

$$K^*_{pt} = H\,(Y_{t-1}, C_t, K_{gt}, \sigma_t) \tag{2}$$

where σ_t is a measure of uncertainty. Because firms cannot instantaneously determine their output and the amount of capital demanded, output is lagged one period in equation (2), which also addresses the potential problem of reverse causality between output and private capital to some degree. Reverse causality is possible because while countries with higher output demand more capital, countries with larger capital stocks also have higher output levels or rates of economic growth. Given the potential for reverse causality between PI_t and Y_t one can instrument for Y_t to address the issue of simultaneity bias. To this end, Y_{t-1} is used as an instrument for Y_t because there will be no simultaneity between PI_t and Y_{t-1}. Thus, gross private investment is defined as

$$PI_t = (K_{pt} - K_{pt-1}) + \delta\, K_{pt-1} \tag{3}$$

Because in the steady state $K^*_{pt} = K^*_{pt-1}$, equation (3) becomes,

$$PI^*_t = \delta\, K^*_{pt} \tag{4}$$

Thus, equation (4) also determines the long run equilibrium level of gross private investment, which can be expressed as,

$$PI^*_t = G\,(Y_{t-1}, C_t, GI_t, \sigma_t, \delta) \tag{5}$$

where GI is gross public investment. This is obtained by implicitly assuming that public capital, K_{gt}, depreciates at the same rate as private capital and that the depreciation rate is time-invariant.

Because of technical constraints, and the time it takes to decide on, build and install new capital, firms cannot instantaneously adjust their actual capital stock to the desired level. A dynamic structure in private capital can be introduced by specifying the cost of adjustment facing the firms in attempting to close the gap between the actual and desired levels of private capital. By taking into account the growing target level of private capital, Nickell [1985] considered a quadratic adjustment cost function which can be expressed in gross private investment as the following form:

$$E\,\{\sum_{i=1}^{\infty} \Omega^i\,[\,\lambda_1\,(PI_{t+i} - PI^*_{t+i})^2 + (PI_{t+i} - PI_{t+i-1})^2 - 2\,\lambda_2\,(PI_{t+i} - PI_{t+i-1})\,(PI^*_{t+i} - PI^*_{t+i-1})]\} \tag{6}$$

where $\lambda_1, \lambda_2 > 0$ are parameters and Ω is the discount factor. PI^*_{t+i} represents the target level of desired gross private investment for period (t+i). The first term in the brackets indicates the cost of not being at the target level. The second term represents the cost of changing the rate of investment. Finally, the last term indicates that the loss is attenuated if the agent moves toward the growing desired level. The firm chooses a sequence of PI_{t+i} to minimize equation (6) given the information at time t, which yields a second-order difference equation. A detailed discussion of the solution to this problem is given by Nickell [1985, 120-122]. The solution to this difference equation yields,

$$(7)\quad \Delta \mathrm{PI}_t = \lambda_2 \Delta \mathrm{PI}_t^* + (1-\mu)[\lambda_2 \mathrm{PI}_{t-1}^* + (1-\lambda_2)(1-\Omega\mu)\sum_{i=1}^{\infty}(\mu\Omega)^i \, \mathrm{E}(\mathrm{PI}_{t+i}^*) - \mathrm{PI}_{t-1}]$$

where Δ represents the first difference and μ is the only stable root in the solution of the difference equation ($|\mu| < 1$). Note that equation (7) reduces to the forward looking partial adjustment mechanism when $\lambda_2 = 0$. Finally, E (PI^*_{t+i}) represents the expected future desired level of investment, which is assumed to have a unit root,

$$(8)\quad \mathrm{E}(\mathrm{PI}^*_{t+i}) = \eta + \mathrm{PI}^*_t$$

where η_i is the drift term. Plugging equation (8) into (7) and rearranging yields

$$(9)\quad \Delta\mathrm{PI}_t = \theta_0 + \theta_1 \Delta\mathrm{PI}^*_t + \theta_2 (\mathrm{PI}^*_{t-1} - \mathrm{PI}_{t-1})$$

where $\theta_0 = (1-\mu)(1-\lambda_2)\,\eta\Omega\mu/(1-\mu\Omega)$, $\theta_1 = [1-\mu(1-\lambda_2)]$, $\theta_2 = 1-\mu$.

Further, the unobservable $\Delta\mathrm{PI}^*_t$ term can be replaced with the first differences of the right hand side variables of a linear approximation of equation (5). Hence the equation becomes,

$$(10)\quad \Delta\mathrm{PI}_t = a_0 + a_1 \Delta\mathrm{Y}_{t-1} + a_2 \Delta\mathrm{C}_t + a_3 \Delta\mathrm{GI}_t + a_4 \Delta\sigma_t - \theta_2 (\mathrm{PI} - \mathrm{PI}^*)_{t-1}$$

This equation shows the short run dynamics of gross private investment, with the last term representing the conventional error correction mechanism. Although the steady state level of private investment, PI*, in the last term is unobservable, it may be recovered by viewing equation (5) as a cointegrating relationship between actual private investment, output, the cost of capital, public investment, and a measure of uncertainty [Guncavdi et al., 1998]. Actual private investment, PI, is first substituted for PI* in equation (5). The long run equilibrium level, PI*, is then proxied by the predicted values from estimating a linear approximation of equation (5). As a result, the last term (error correction term) in equation (10) is the lagged residuals from the cointegrating equation (5). It is worth noting that the last term can also be represented by $(PI_{t-1} - \hat{P}I^*_{t-1})$, a point that becomes clearer in the result section.

The availability of credit is a crucial determinant of private investment in developing countries. The credit constraint is more important in developing than developed countries partly because equity markets are not as developed. In addition, controls over interest rates and credit rationing in the financial markets of many developing countries reduce the role of the interest rate in rationing credit while highlighting the significance of credit availability. Therefore, most of the previous studies such as Blejer and Khan [1984] and Ramirez [1994] include the amount of credit available to private investors into the model. The availability of credit is likely to influence the adjustment of actual investment toward its desired level, altering only the short run dynamics of private investment. The estimating equation then becomes,

$$(11)\quad \Delta PI_{i,t} = a_0 + a_1 \Delta Y_{i,t-1} + a_2 \Delta C_{i,t} + a_3 \Delta GI_{i,t} + a_4 \Delta\sigma_{i,t} + a_5 \Delta CRD_{i,t} - \theta_2 (PI - PI^*)_{i,t-1} + v_{i,t}$$

where ΔCRD_t denotes the flow of external credits to private sector and $v_{i,t}$ is a random disturbance. The subscripts i = 1,..., N and t = 1,..., T represent the cross-section and time-series dimension of the panel data. θ_2 is the error correction coefficient which indicates the speed at which the private investment adjusts toward its long run equilibrium in each short run period. A novel feature of this approach is that one can estimate both the long run (from a linear approximation of equation (5)) and short run (from equation (11)) dynamics of private investment.

Tests such as Augmented Dickey-Fuller (ADF) can be applied to determine whether the variables in equation (5) are co-integrated for each country in the sample. However, these tests are quite sensitive to the number of observations, and are not robust when the data covers a short time span as is the case in this study [Coiteux and Olivier, 2000]. Thus, no attempt is made to perform these tests for each individual country in the sample. Instead, a t-test of the estimated q_2 can be used to see whether the error correction term is significantly negative [Guncavdi et al., 1998]. The finding of a significant and negative adjustment coefficient can be taken as evidence that there is a cointegrating relationship and that the error correction specification is well defined. An alternative is to perform unit root tests with the pooled data as suggested by Levin and Lin [1992, 1993]. If the residuals obtained from estimating equation (5) do not have a unit root, then equation (5) is a cointegrating vector, which empirically justifies the use of the error correction specification (11). Accordingly, a panel unit root test, which is basically a panel version of Dickey-Fuller test for time series, is performed by estimating the following regression,

$$(12)\quad \Delta \varepsilon_{i,t} = a + b_i \varepsilon_{i,t-1} + \xi_{i,t}$$

where Δ denotes the first difference operator and $\varepsilon_{i,t}$ represents the residuals obtained from estimating equation (5). $\xi_{i,t}$ is a stationary disturbance term. To carry out the panel unit root test, equation (12) is estimated by the pooled-OLS method because the residuals are obtained from estimating the long run regression by the fixed effect method, which eliminates the fixed country effects from the residuals. Entertaining the null hypothesis that $b_i = 0$ enables us to determine whether the residuals have a unit root. If one rejects the null, then the residuals are stationary series. This means that the variables of interest are co-integrated and equation (5) is a cointegrating vector. Therefore, in the second stage, one can estimate equation (11), called the Engle and Granger two step procedure [Engle and Granger, 1987].

Following this line of analysis, a linear approximation of equation (5) is estimated by the FE estimator, from which the residuals are obtained. Then, using equation (12), the panel unit root test on the residuals is performed to see whether the error correction model can be justified empirically. It is, so the error correction model (equation 11) is estimated. Because equation (11) is in first differences, which eliminates country specific effects as well, it can be estimated using pooled-OLS or Fixed effect specification. To see which estimator is preferable, an F-test is performed to test the hypothesis that all constant terms are equal across countries.

Proxy for Uncertainty

The generalized autoregressive conditional heteroscedasticity specification (GARCH) developed by Bollerslev (1986) has recently become a popular specification for modeling volatility. The GARCH process captures an important part of reality by assuming that uncertainty is time variant because it may be greater during the bad states than during the good states of the economy. Following the lead of the studies by Price [1995; 1996], Serven, [1998], and Dehn, [2000], a simple univariate model of GARCH (1, 1) is specified to obtain uncertainty measures,

$$x_t = \phi_0 + \phi_1 t + \phi_2 x_{t-1} + \upsilon_t; \qquad t = 1,\ldots, T; \tag{13}$$

$$\sigma^2_t = \zeta_0 + \zeta_1 \upsilon^2_{t-1} + \zeta_2 \sigma^2_{t-1} \tag{14}$$

where $\upsilon_t \sim N(0, \sigma_t)$ and σ^2_t shows the variance of υ_t conditioned on an information set up to period t. Equation (13) is an AR(1) process with a deterministic time trend that separates out the predictable and unpredictable components while equation (14) is a GARCH(1,1) process that allows for heteroskedasticity in the unpredictable component. The fitted values of the conditional variance from equation (14) provide a proxy for uncertainty.

At this point, the volatility of what variable or variables, x_t, are chosen to represent uncertainty becomes another important issue. Many macroeconomic variables may be viewed as a source or an indicator of uncertainty. In this study, the rates of inflation, output growth and the real exchange are taken as the main indicators of overall macroeconomic instability. First, the conditional variances of these variables are obtained from estimating the above GARCH process for each country. Second, following the analysis of Serven [1998], a summary measure of uncertainty is constructed using the volatility measures (conditional variances of the variables in question). To accomplish this, a principal component analysis is carried out for each country across time, which allows us to combine the volatility measures into a single proxy that retains most of the variation in these measures. That is, this method looks for a linear combination of highly correlated variables to yield principal components in a way that accounts for the maximum variation in these variables. Therefore, the first principal component of the volatility measures is used as a proxy for uncertainty.

Data Sources and Description of Variables

The main sources of the data are from Bouton and Sumlinski [2000] of the International Finance Corporation of the World Bank, (B&S, IFC), the International Monetary Fund, International Financial Statistics Yearbook, 2000 and 1999 issues (IFS).

The data on gross private and public fixed investment are obtained from B&S, IFC that compiles the ratios of public and private investment to GDP for 50 developing countries spanning from 1970 to 1998. Because some countries lack observations for several years, 21 out of 50 have the complete data for 1970-1998 periods. However, because of the data limitations on the other remaining variables compiled from IFS, there are few countries (only 6) that have complete data for 1970-1998 periods. As a result, we restrict the time span to the years 1980-1997, for which complete data for 19 developing countries are available (Bangladesh, Belize, Chile, Costa Rica, Ecuador, Guatemala, India, Kenya, Korea, Malaysia, Malawi, Mauritius, Mexico, Pakistan, Philippines, Thailand, Tunisia, Turkey, and Uruguay). Because of the diversity of countries in the sample (4 from Africa, 7 from Western Hemisphere, and 8 from Asia including Turkey), the country set appears to be fairly representative of developing countries around the world. It is also worth noting that the panel is chosen to be balanced, which requires complete data from each country that cover the same time span.

Output, Y, is proxied by real gross domestic product (GDP). Nominal GDP (taken from IFS, line 99b) is converted into real GDP by the GDP deflator (taken from IFS, line 99bi). Thus real GDP is expressed in national current prices in 1995. Only the data on nominal GDP and GDP deflator for Turkey are taken from the national data sources (the State Planning Organization of Turkey, 1997 issue). The dependent variable, real gross private investment, PI, is obtained by multiplying the ratios of gross private investment to GDP (taken from B&S, IFC) by real GDP. Real gross public investment, GI, is calculated by multiplying the ratios of gross public investment to GDP (taken from B&S, IFC) by real GDP. Nominal bank credit to the private sector (taken from IFS, line 32d) is converted into real terms by the GDP deflator. Thus real bank credit, CRD, is expressed in national current prices in 1995.

The uncertainty measure, σ, is the first principal components of the conditional variances of the inflation rate, output growth (real GDP growth) rate and real exchange rate obtained from estimating GARCH (1, 1) process. The inflation rate is calculated as the annual difference in the logs of the country's consumer price index (CPI taken from IFS, line 64), with base 1995=100. Due to the unavailability of complete data on CPI for Bangladesh and Tunisia, the GDP deflator and PPI are used respectively. The real exchange rates per US dollar are computed by the PPP condition that $\log REXC = \log\{EXC * [CPI(US) / CPI]\}$ where EXC is nominal exchange rate (taken from IFS, line ae) and CPI(US) is the consumer price index of the US with base1995=100. The real GDP growth rate is computed as the annual difference in the logarithm of the real GDP.

The user cost of capital, C, is proxied by the real interest rate which is calculated using the formula $\log [(1+NINT_t) / (1+INF_t)]$ where INF and NINT denote respectively inflation rate and nominal interest rate (taken from IFS, lines 60b, 60l, and 60). Unfortunately, the definitions of interest rates vary across countries due to the lack of available data. The money market (commercial bank) rate for India, Malaysia, Mauritius, Pakistan, Thailand, S. Africa, deposit rates for Bangladesh, Belize, Chile, Guatemala, Korea, Malawi, Mexico, Philippines, Turkey, Uruguay, and discount rates for Colombia, Costa Rica, Ecuador, Kenya, Tunisia are used.

RESULTS

Measuring Uncertainty

The model treats the inflation rate, real exchange rate, and growth rate as potential sources of macroeconomic instability. To distinguish predictable and unpredictable components in these variables, equations (13) and (14) are estimated for each variable and country in the sample. After obtaining the fitted values of the conditional variances of these variables, a summary proxy for uncertainty is constructed to represent overall macroeconomic instability. A principal component analysis is performed to weight the conditional variances of these variables for each country across time. For the majority of countries, the first principal component has positive loadings on the unpredictable component of each variable. The largest weights correspond respectively to the inflation rate, real exchange rate and growth rate uncertainty measures. Further, the first principal component accounts for around 60 percent of the variation in the individual uncertainty measures. Overall, the first principal component accounts for a high percentage of the variation in the conditional variances and has positive loadings for the majority of the countries, which implies that the first principal component can be used as a summary measure of uncertainty.

Estimation Results

In order to justify and estimate the error correction model, we exploit the notion that equation (5) represents a co-integrating relationship between actual private investment and the right-hand side variables. If they are co-integrated, this means that they move together toward a steady-state equilibrium and hence equation (5) indicates a stable long run equilibrium relationship that can be estimated by the conventional estimation techniques. In this case, one can posit and estimate the error correction representation of the neoclassical model of private investment in the second stage. The first stage, a linear approximation of the co-integrating (long-run equilibrium) equation (5), is estimated using the fixed effect specification, with all variables converted to logs. The results are reported in Table 1. Before interpreting the results reported in the table, one needs to investigate the question of whether these specifications can be taken as a co-integrating relationship because the two-step procedure is valid if there is evidence of cointegration.

If the residuals from the long run relationship follow a stationary process, then the variables of interest are co-integrated. To test whether the residuals have a random walk, a panel unit root test on the residuals is performed using equation (12). Because the conventional t critical values are not valid for a panel unit root test, Levin and Lin [1992] obtained critical values under the null hypothesis that all slopes across cross sectional units are equal to zero. When equation (12) is estimated by the pooled-OLS, Levin and Lin critical values with 15 and 19 degrees of freedom at 1 and 5 percent levels of significance are respectively -2.64 and -1.94. The t statistic, -3.54, is greater in absolute value than the critical values, leading to the rejection of the hypothesis that the residuals from the long run regressions have a unit root. Therefore, one can conclude that the actual private investment and the right-hand side variables in the long run equilibrium relationship are co-integrated.

TABLE 1
Long-run Equilibrium Relationship

Dependent Variable: Real Private Investment $_t^a$	Fixed Effect
Constant	–––
Real GDP$_{t-1}^a$	0.763
	(0.223)***
Real Interest Rate $_t$	-0.198
	(0.192)
Real Public Investment $_t^a$	0.534
	(0.191)***
Uncertainty^b $_t$	-0.057
	(0.017)***
Total Panel Observations	304
Balanced Sample	1982-1997
Number of Countries	19
Adjusted R^2	0.996
D-W	1.29**

Notes: Asterisks (*), (**), and (***) indicate 10, 5, and 1 percent significance levels respectively. Figures in the parentheses are heteroscedasticity consistent standard errors.

a. Expressed in logarithms.

b. The first principal components of the conditional variances of the inflation rate, growth rate and the log of exchange rate obtained from a univariate GARCH(1,1) process for each country in the sample, as shown in Serven (1998).

Accordingly, the FE estimates in Table 1 can be interpreted as the coefficients that represent the long-run relationship. However, one should not make statistical inferences on the significance of the estimated coefficients because of the possibility of autocorrelation. As seen from the FE estimates, the standard variables have correct signs, suggesting that private investment is positively related to real output and negatively to the real interest rate in the long run. The results also indicate that public investment has a positive impact on private investment. Furthermore, the summary measure of uncertainty carries a negative sign in the long run equilibrium relationship.

Given evidence of co-integration, the lagged residuals obtained from the long-run regression represent the deviations from long run equilibrium and correspond to the error correction term (EC). The next step is to estimate the short run dynamics of private investment, using the error correction model (equation 11). Table 2 reports the pooled-OLS and FE estimates of the error correction model. First, note that the estimated coefficients of the error correction terms in both regressions carry a negative sign and they are significant at 1 percent level. This can also be taken as evidence that the variables defined in the cointegrating relationship move toward a stable long-run equilibrium (Guncavdi et al., 1998). Also, the D-W statistics show the absence of a first order serial correlation. The F statistic with 18 and 260 degrees of freedom indicates that the hypothesis that all constant terms are equal cannot be rejected at any conventional level of significance, meaning that fixed country effects are insignificant. Accordingly, the pooled-OLS estimator can be chosen as the preferred specification. However, regardless of the specification of the country effects, the results are similar in both columns of Table 2. As discussed earlier, the coefficient of the error correction term represents the speed at which the actual private investment adjusts to its desired (steady state) level. The speed of adjustment is estimated at around 39 percent, which implies that 39 percent of the adjustment in the actual private investment toward its long run level takes place within a year.

TABLE 2
Error Correction Model: Short-run Determinants of Private Investment in Developing Countries

Dependent Variable: DReal Private Investment $_t$[a]	**Balanced Sample: 1982-1997 Number of Countries: 19**	
	Pooled-OLS	**Fixed Effect**
Constant	0.014	___
	(0.013)	
D Real GDP $_{t-1}$[a]	0.148	0.148
	(0.137)	(0.149)
D Real Interest Rate $_t$	-0.102	-0.083
	(0.209)	(0.221)
D Real Public Investment $_t$[a]	0.274	0.265
	(0.087)***	(0.087)***
D Uncertainty $_t$	-0.009	-0.008
	(0.010)	(0.009)
D Real Credit $_t$[a]	0.549	0.568
	(0.109)***	(0.108)***
Error Correction (EC $_{t-1}$)	-0.394	-0.389
	(0.089)***	(0.091)***
Total Panel Observations	285	285
Adjusted R^2	0.56	0.537
D-W	1.98	2.01
F-stat (pooling)		0.72

Notes: Asterisks (***) indicates 1 percent significance level. Figures in the parentheses are heteroscedasticity consistent standard errors.
a. Expressed in logarithms.

The signs of the variables accord with the theoretical expectations. While GDP, the real interest rate, and uncertainty do not affect the short run dynamics of private investment, public investment and credit availability have significant impacts on private investment in the short run. Taken as a whole, real GDP has a strong accelerator effect on private investment in developing countries in the long term. While the real interest rate has no effect on the short run dynamics of private investment, the results consistently indicate that the flow of real credit to the private sector affects private investment in the short run. There are several potential explanations for this. First, this finding supports the argument that the quantity constraints on bank credit, resulting from the less developed financial markets in developing countries, have a larger impact on private investment than the cost of capital. Second, private firms and investors may not respond to the changes in real interest rate because of uncertainty surrounding the real cost of capital. The results also indicate that the summary measure of uncertainty captures the negative impact of overall macroeconomic instability in developing countries only in the long run. The primary conclusion of this empirical model is that there is strong evidence that public investment complements private capital in the long run and short run, which is in agreement with the majority of the earlier studies such as Blejer and Khan [1984], Greene and Villanueva [1991], Oshikoya [1994], and Odedokun [1997].

CONCLUSION

An ongoing issue in the literature on investment in developing economies is the impact of public investment on private investment. The previous literature has provided inconsistent results, and this study uses a panel data set of 19 developing countries from 1980 to 1997 to re-examine the issue, offering several econometric advances over previous studies. This study begins by deriving a reduced-form neoclassical model of private investment that allows the estimation of both the short-run and long-run determinants of investment. The time series properties of the data can have an effect on the estimates, and this study performed co-integration tests to confirm that the data set represent a long-run co-intergrated relationship. The model also incorporates a measure of macroeconomic uncertainty, which can affect private investment.

The main empirical result is that, in accordance with a substantial share of the previous literature, public investment is complementary to private investment. The results show that in the long run, a one percent increase in public investment will result in an increase in private investment of about 0.54 percent. The short-run impact is also positive, but about half as large. The results also show that the interest rate does not have a statistically significant impact on the level of investment, but that credit availability to the private sector does. This suggests that imperfections in the credit market play a significant role in inhibiting private investment in developing economies. Macroeconomic uncertainty also has a negative impact in the long run, although its short-run impact is insignificant. From a policy perspective, these results show the importance of public investment as a stimulus to private investment in developing economies, and also show that, perhaps because of less-developed financial institutions or because of financial regulations, the availability of credit is a constraining factor on private investment in developing economies.

NOTES

The authors gratefully acknowledge helpful comments from two anonymous reviewers of this Journal, Charles Barrilleaux, David Rasmussen, and especially Stefan Norrbin.

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